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The effect of a comprehensive injury audit program on injury incidence in ballet: a 3-year prospective study

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Corresponding Author:	Nick Allen, M.Sc. (Sports Med) Birmingham Royal Ballet Birmingham, UNITED KINGDOM
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Birmingham Royal Ballet
Corresponding Author's Secondary Institution:	
First Author:	Nick Allen, M.Sc. (Sports Med)
First Author Secondary Information:	
Order of Authors:	Nick Allen, M.Sc. (Sports Med)
	Alan Neville, PhD
	John Brooks, PhD
	Yiannis Koutedakis, PhD
	Matt Wyon, PhD
Order of Authors Secondary Information:	
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Abstract:	Abstract Objective: The aim of this study was to determine whether an intervention with individualized conditioning program based on past injury history and functional movement screening would be effective in reducing ballet injury incidence. Design: Prospective three year epidemiological study. Setting: Professional Ballet Company and its in-house medical facility. Participants: Dancers from a professional ballet company over the three year study period. Participant numbers ranged from 52 to 58 (Year 1: 52; Year 2: 58; Year 3: 53). Interventions: The intervention consisted of individual conditioning programs developed using injury history and functional movement screening. Analysis was undertaken of the all dancers who were present in the company during the study period. The significance of change in injuries over a 3-year period was determined using a Poisson distribution model. Main Outcomes Measurements: To determine whether individual conditioning programs resulted in a decrease in injury incidence over the study period. Results: The injury count reduced significantly in Year 2 and 3 (P<.001). Injury incidence for male dancers declined from Year 1 (4.76/1000hrs) to Year 2 (2.40/1000hrs) and Year 3 (2.22/1000hrs). For females, a reduction in the injury incidence was observed in Year 2 (1.71/1000hrs) and Year 3 (1.81/1000hrs) compared to Year 1 (4.14/1000hrs). Conclusions: Through prospective injury surveillance we were able to demonstrate the benefit of individualized conditioning programs based on injury history and functional movement screening in reducing injuries in ballet.

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Table

Table 1: Anthropometric details of the current participants by gender and year

	Gender (no.)	Age (yrs) [SD]	Height(cm)[SD]	Weight(kg)[SD]
Year 1	Male (n=25) Female (n=27)	23 [4] 25 [5]	179 [4.3] 162[3.9]	71.5 [4.7] 49.2 [4.04]
Year 2	Male (n=29) Female (n=29)	24 [4] 25 [5]	179 [1.0] 162 [0.96]	71.5 [4.73] 49.2 [4.05]
Year 3	Male (n=26) Female (n=27)	24 [4] 26 [5]	179 [5.3] 164 [3.6]	72.2 [7.01] 51.2 [5.59]

Table 2: Injury Incidence for female and male dancers' for Years 1, 2 and 3

	Overall		Female		male	
	Injury incidence (95%CI)	Average Severity (Days) (95%CI)	Injury incidence (95%CI)	Average Severity (Days) (95%CI)	Injury incidence (95%CI)	Average Severity (Days) (95%CI)
Year 1	4.44 (4.00-4.93)	7 (6-8)	4.14 (3.57-4.81)	4 (3-5)	4.76 (4.12-5.51)	9 (8-11)
Year 2	2.05 (1.78-2.37)*	9 (8-10)	1.71 (1.36-2.13) *	5 (4-7)	2.40 (1.99-2.90) *	11 (9-14)
Year 3	2.02 (1.74-2.35)*	11 (10-13)	1.81 (1.44-2.27) *	15 (12-19)	2.22 (1.82-2.70) *	8 (7-10)

Table 3: Injury Incidence for female dancers by year and type (Overuse/Traumatic)

	Year 1			Year 2			Year 3		
	Number of injuries (% of all injuries)	Injury incidence (95%CI)	Average Severity (Days) (95%CI)	Number of injuries (% of all injuries)	Injury incidence (95%CI)	Average Severity (Days) (95%CI)	Number of injuries (% of all injuries)	Injury incidence (95%CI)	Average Severity (Days) (95%CI)
Overuse	117 (68)	2.82 (2.35-3.38)	3.(3- 4)	48 (63)	1.08 (0.81-1.43)	5 (4-7)	49 (65)	1.18 (0.89-1.56)	17(13-23)
Traumatic	55 (32)	1.33 (1.02-1.73)	6(4-8)	28 (37)	0.63 (0.43-0.91)	5 (4-8)	26 (35)	0.63 (0.43-0.92)	11(8-16)
ALL INJURIES	**172 (100)**	**4.14 (3.57-4.81)**	**4(3-5)**	**76 (100)**	**1.71 (1.36-2.13)**	**5(4-7)**	**75 (100)**	**1.81 (1.44-2.27)**	**15(12-19)**

Table 4: Injury Incidence for and male dancers by year and type

(Overuse/Traumatic)

	Year 1			Year 2			Year 3		
	Number of injuries (% of all injuries)	Injury incidence (95%CI)	Average Severity (Days) (95%CI)	Number of injuries (% of all injuries)	Injury incidence (95%CI)	Average Severity (Days) (95%CI)	Number of injuries (% of all injuries)	Injury incidence (95%CI)	Average Severity (Days) (95%CI)
Overuse	110 (60)	2.84 (2.35-3.42)	9 (8-11)	41 (38)	0.92 (0.70-1.02)	6(4-8)	39 (40)	0.87 (0.60-1.20)	11(8-14)
Traumatic	73 (40)	1.93 (1.53-2.42)	10(8-12)	66 (62)	1.48 (1.20-1.90)	15(12-19)	60 (60)	1.35 (1.00-1.70)	7(5-9)
ALL INJURIES	**183 (100)**	**4.76 (4.12-5.51)**	**9 (8-11)**	**107 (100)**	**2.40 (2.00-2.90)**	**11(9-14)**	**99 (100)**	**2.22 (1.80-2.70)**	**8(7-10)**

Table 5. Mean and range FMS scores: Year 1, 2 and 3.

	Functional Movement Screen (score out of 21)	
Year	**Mean (%)**	**Range (%)**
1	15 (71)	11-19 (52-95)
2	14 (66)	9-17 (42-80)
3	13 (62)	10-16 (47-75)

Figure

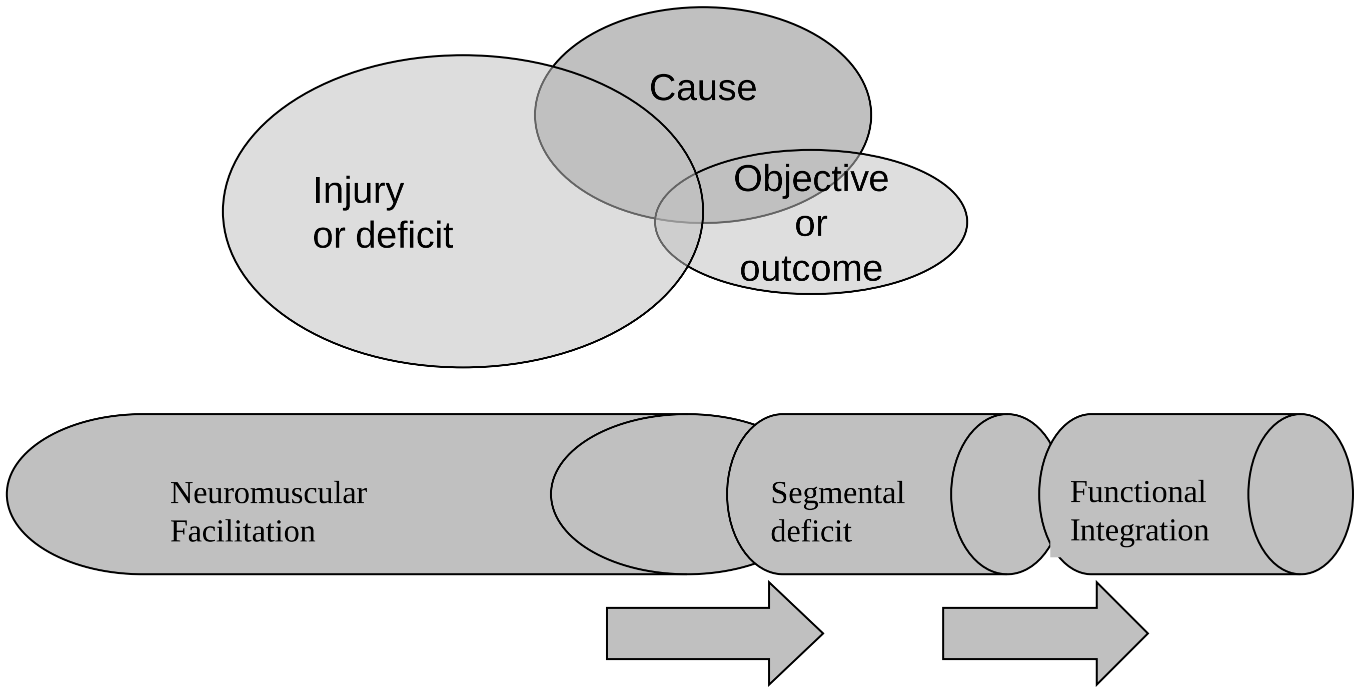
Cause
Injury
or deficit
Objective
or
outcome
Neuromuscular
Facilitation
Segmental
deficit
Functional
Integration

Figure 1: Graphic representation of the Hybrid Intervention Model and intervention program construction (early stage)

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Title page

The effect of a comprehensive injury audit program on injury incidence in ballet: a 3-year prospective study

Nick Allen M.Sc.[1,2,6]; Alan M. Nevill PhD[2]; John H.M. Brooks PhD[3].; Yiannis Koutedakis PhD[2,4,5]; Matthew A. Wyon PhD[1,2,6]

[1]The Jerwood Centre, Birmingham Royal Ballet Company, Birmingham, UK

[2]Research Centre for Sport Exercise and Performance, University of Wolverhampton, Walsall, UK

[3] Rugby Football Union, Twickenham, UK

[4] Exercise Sciences, University of Thessaly, Trikala, Greece

[5] Institute of Human Performance and Rehabilitation, Trikala, Greece

[6] National Institute of Dance Medicine and Science, London, UK

Corresponding author

Nick Allen M.Sc. (Sports Med), B.Sc. (Hons), MCSP SRP

Birmingham Royal Ballet

Thorp Street

Birmingham

B5 4AU

United Kingdom

+44(0)1212453566

nickallen@brb.org.uk

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Abstract

Main text

Abstract

Objective: The aim of this study was to determine whether an intervention with individualized conditioning program based on past injury history and functional movement screening would be effective in reducing ballet injury incidence.

Design: Prospective three year epidemiological study.

Setting: Professional Ballet Company and its in-house medical facility.

Participants: Dancers from a professional ballet company over the three year study period. Participant numbers ranged from 52 to 58 (year 1: 52; year 2: 58; year 3: 53).

Interventions: The intervention consisted of individual conditioning programs developed using injury history and functional movement screening. Analysis was undertaken of the all dancers who were present in the company during the study period. The significance of change in injuries over a 3-year period was determined using a Poisson distribution model.

Main Outcomes Measurements: To determine whether individual conditioning programs resulted in a decrease in injury incidence over the study period.

Results: The injury count reduced significantly in year 2 and 3 (P<.001). Injury incidence for male dancers declined from year 1 (4.76/1000 hrs) to year 2 (2.40/1000 hrs) and year 3 (2.22/1000 hrs). For females, a reduction in the injury incidence was observed from year 1(4.14/1000 hrs) to year 2 (1.71/1000 hrs) and year 3 (1.81/1000 hrs) year/1000 hrs.

Conclusions: Through prospective injury surveillance we were able to demonstrate the benefit of individualized conditioning programs based on injury

history and functional movement screening in reducing injuries in ballet.

Key Words:

Ballet; injury; risk; screening, intervention, conditioning program

Clinical Relevance: The implementation of well structured injury surveillance programs can impact on injury incidence through its influence on intervention programs.

Introduction

Reducing injuries within sport has been a challenge since classical years and the ancient Olympic Games.[20] Artistic athletes like dancers[16,19] are exposed to extreme physical demands[21,37] and subject to risk of injury[17,35,38] with injury rates varying from 0.62-5.6 injuries/1000 hrs.[15,22,29] Injury has been reported to be multi-factorial[4,24,25] and so strategies to prevent injuries may also need to be multi-factorial. Understanding injury risk, through establishing the extent of injury along with potential intrinsic risk factors, are key elements from which interventions can be planned and tested. Use of injury history and pre-participation screening data regarding musculoskeletal risk factors has been suggested in sports medicine.[14]

In dance medicine literature, however, there are few epidemiological and screening studies from which interventional strategies for injury prevention can be evaluated. Bronner, et al [6] set out to determine the effect of implementing on-site medical care on in a modern dance company. The results revealed a significant reduction in workers compensation cases in the following three years. Similarly the positive impact of moving from an insurance-based funded system to an “in-house” medical care system for a professional ballet company has been reported over a period of 5 years. [32] Both studies have demonstrated the impact on injury incidence with the implementation of in-house medical care. Nevertheless, it is still unknown the impact of combining injury audit data with screening data in the construction of conditioning plans on injury incidence in a ballet company that already has comprehensive in-house medical provision. Therefore the aim of this study was to evaluate changes in injury incidence following the implementation of individual intervention programs using results of a specially designed injury audit and screening program.

Methods

Procedures

This study has been based on Van Mechelen's injury prevention model.[39] The first stage was implementing an injury surveillance program starting at year 1, continuing throughout the three-year study period. At the beginning of year 1, a pre-season screening program, the Functional Movement Screen (FMS), was implemented. In year 1, injury prevention program was undertaken based on the FMS. In year 2 and 3 interventions were based on the FMS and injury surveillance data. The intervention consisted of individual conditioning programs developed using the Hybrid Intervention Model (HIM). The HIM was developed by the lead author as a means to create a format, based on clinical reasoning, to create consistency in the conditioning programs to all dancers. The effect was then evaluated at the end of year 2 and year 3 through injury audit.

Participants

The study prospectively followed a professional ballet company over three performance years (year 1: 2005-2006; year 2: 2006-2007; year 3: 2007-2008). The company consisted of between 52 and 58 dancers (year 1: 52; year 2: 58; year 3: 53). Data was collected on all dancers within the company during the study period (Table 1). The study was approved by the University of Wolverhampton's ethics committee.

Injury Surveillance

The injury audit provided both a global picture of injuries, and a valuable database to analyze individual's injuries against the rest of the cohort. The present study was consistent with international consensus documents on injury surveillance in sport.[12,13,31] A time-loss definition of injury was used whereby "any injury that prevented a dancer from taking a full part in all dance related activities that would normally be required of them for a period equal to or greater than 24 hours after the injury was sustained". [1] Injuries were classified either as traumatic: "an injury that resulted from a specific identifiable event" or overuse "an injury caused by repeated micro-trauma without a single identifiable event responsible for the injury".[12] A recurrent injury was defined as: an injury of the same type and at the same site as the index (first episode) injury, occurring after a dancers´ return to full participation from the index injury within 2 months (definitions modified from Fuller et al[12]). Injuries were prospectively recorded by the in-house physiotherapists. All dancers were injury free at the start of the study. Dancers participated in 145 performances of 15 different shows in year 1, 143 performances of 18 different shows in year 2, and 142 performances of 20 different shows in year 3, averaging 7 performances per week during performance periods. Exposure was calculated by the lead researcher using estimations based on detailed call sheets and performance schedules as well as the dancers' union contract that determined the amount of allowable dance related activity.

Functional Movement Screen (FMS)

The FMS uses 7 movement tests on a 4 point scale[18,26] the deep squat; the hurdle step; the in-line lunge; the shoulder mobility test; the active straight leg raise (ASLR); the trunk stability push-up; and the rotary stability test.[9,10]. A notable aspect of the FMS in relation to other dance screening [33,36] is the absence of any dance specific testing. All screening was administrated (by NA) in the first two weeks at the beginning of the performance year, after the dancers' return from a 5 week off-season break.

The FMS [18,26] was used to assess the "ability" and "quality" of normal movement patterns. An analysis of the individual test movements to determine dancer's asymmetries and compensatory movements for determining an overall score and risk assessment based on generic criteria.

The outcomes were used to design individualized conditioning programs.

There could be a risk of performance loss (and injury) if the movement was achieved by compensation elsewhere. Therefore the impact of stabilization at the lumbopelvic region was closely monitored. The sacroiliac joint provides a key link in the overall kinetic chain between the lower limb and hip, and the trunk.[6,7] Part of the stabilization of this region is through compressive force closure due to muscles, ligaments and fascia.[32] If these are weak or insufficient they affect sacroiliac stability[32] and load transfer through the pelvic girdle.[6,7] The FMS allowed the nature of pelvic/hip compensations to be identified- in particular with the "deep squat" and "in-line lunge" tests.

Hybrid Intervention Model (HIM)

Using observations of key performance attributes from elite sport and dance, the HIM was developed to construct individual conditioning programs. It was important that the same model could be applied to the design of conditioning programs for dancers with an injury, as well as dancers for whom a performance enhancement potential or injury risk was identified. The model incorporated the skill and "efficiency of movement" characteristics noted with elite dancers, together with the fitness and strength attributes of "traditional" elite sports athletes. The hybrid component looks to combine movement efficiency with strength training within the conditioning program in a cross-training approach.

The HIM considers three points in each program: the injury or deficit; the cause of the injury or deficit; and the final outcome. The model looks to identify which of the three is the key "limiting factor" for the current stage (for example acute/early stage, sub-acute/mid stage, or chronic/late stage) of the injury/deficit. This then influences the relative ratios of the three components that are combined to form individual conditioning programs. The components are neuromuscular facilitation, isolated segmental deficit training, and functional integration. In the early stage of an injury or deficit, the key limiting factor may be the injury/deficit itself, with the cause and end stage objective carrying less immediate importance or weighting (fig 1).

The development of correct neuromuscular control and movement efficiency patterns has been hypothesized to be essential to provide a safe load to an injured/deficient region without risk of injury or compensatory movement or muscular patterns. The segmental deficit component identifies the muscle group(s) within the movement chain that is influential to the overall function but is deficient, and looks to improve it. The last component of the program is “functional integration”. In early stages these may be in unloaded postures that replicate functional activities, like jumping, but taking place on a Pilates reformer (a supine spring-based exercise machine on which a series of exercises can be carried out and resistance varied according to the number of springs employed or in a pool before being carried out in the studios.

Progressing with the model though to “end stage”, the main limiting factor may be the proposed outcome set rather than the injury or cause. Thus conditioning program has a smaller emphasis coming from the neuromuscular and segmental deficit components of the program and a larger emphasis on the functional integration. This ensures the efficiency of the movement patterns alongside the strength and function work. Each dancer’s program was facilitated by the lead researcher and developed by consensus with and delivered by the multi-disciplinary medical team employed by the company.

Statistical analysis

The severity of injuries was calculated as the number of days between the date of injury and date of return and reported as mean severity with 95% confidence intervals. The incidence of injury was calculated as the number of injuries per 1,000 hours of dancing with 95% confidence intervals. A Poisson distribution model was used to calculate CIs. The injury count was analysed assuming a Poisson distribution (Eq. 1) using the MLwin software (Version 2.22, Centre for Multilevel Modelling, University of Bristol, UK).

$$\text{Injuries} \sim \text{Poisson}(\pi_i) \quad \text{(Eq. 1)}$$

Because injury frequencies are counts, the number of injuries are analyzed using a log link. For the current injury data, we wanted to assess the effect of years on the number of injuries using the following model

$$\text{Log}(\pi_i)=\text{cons} + \beta_2{*}\text{year2} + \beta_3{*}\text{year3},$$

where cons is the constant intercept parameter (for year 1) and β_2 and β_3 is the estimated difference due to years 2 and 3 respectively.

Results

In year 1 (2005-2006) 355 injuries (female 172; male 183) were reported, with 183 injuries in year 2 (female 76; male 107) and 174 injuries in year 3 (female 75; male 99). Overall exposure periods were 79924 hours in year 1 compared with 89146 in year 2 and 86072 in year 3. Female dancers' exposure was 41499 hours in year 1, 44573 hours in year 2 and 41499 hours in year 3. Exposure periods increased for male dancers from year 1 (38425) to 44573 in year 2 and year 3. In respect to injury count the software estimated:

$$\text{Log}(\pi_i)=1.854(\text{SE}=0.052)–0.675(\text{SE}=0.089){*}\text{year2}-0.832\ (\text{SE}=0.094){*}\text{year3}.$$

where the SE=standard error of the estimate. The decline in year 2 was found to be -0.675 (SE=0.089: P<.001) and the decline by year 3 was also significant -.832 (SE=0.094; P<.001). By taking antilogs, the estimated mean injuries per dancer for years 1, 2 and 3 were:

year 1 = exp (1.854) =6.39

year 2 = exp (1.854-0.675=1.179) =3.25

year 3 = exp (1.854-0.832=1.022) =2.78

From observing the parameter estimates and the SE for years 2 and 3, the decline in the mean number of injuries per dancer in years 2 and 3 are highly significant (both more than 7 times their SE). There was a decrease in injury incidence for all dancers between year 1 and years 2 and 3. The injury incidence for male dancers declined from year 1 (4.8/1000 hrs) to year 2 (2.4/1000 hrs) and year 3 (2.2/1000 hrs). A similar reduction in incidence of injuries for female dancers was observed in year 2 (1.7/1000 hrs) and year 3 (1.8/1000 hrs) compared to year 1 (4.1/1000 hrs). The mean injury severity in year 1 was 7 days (female: 4 days; male: 9 days). In year 2, this increased slightly for both male and female dancers to 9 days, (female: 5 days; male: 11 days). In year 3, there was a further increase in injury severity (11 days), with female dancers reporting an increase while male dancers reported a decrease (female: 15; male 8 days) TABLE 2. In year 1, the incidence of recurrent injuries for female dancers was 1.64/1000 hrs representing 40% or the total number of injuries sustained by the female dancers. In year 2 and year 3, this reduced to 0.61/1000 hrs and 36%, and 0.46/1000 hrs and 25% respectively. In male dancers, the recurrent incidence was 1.51/1000 hrs and 32% of the total number of male injuries in year 1, which reduced to 0.47/1000 hrs and 20%, and 0.43/1000 hrs and 20% in year 2 and year 3 respectively.

The incidence in female dancers overuse injuries was consistently higher than traumatic injuries (year 1: 2.82/1000 hrs; year 2: 1.08/1000 hrs; year 3: 1.2/1000 hrs) and accounted for a greater percentage of time loss (year 1: 54%; year 2: 63%; year 3: 75%) (Table 3). Female dancers recorded reductions in both overuse and traumatic injuries between year 1 and year 2 (overuse: 61.70%; traumatic: 52.63%), while between year 2 and year 3, overuse injuries increased by 8.47%, while traumatic injuries remained the same. The incidence of male overuse injuries was higher in year 1 (2.84 /1000 hrs dance) and accounted for a greater percentage of time loss (58%), while traumatic injuries were higher in year 2 (1.48/1000 hrs) and year 3 (1.35/1000 hrs) and accounted for the greatest percentage of time loss (year 2: 80%; year 3: 51%) (Table 13). Male dancers recorded reductions in both overuse and traumatic injuries between year 1 and year 2 (overuse: 67.60%; traumatic: 23.31%) and year 2 and year 3 (overuse: 5.43%; traumatic: 8.78%) (Table 4). The results of the FMS remained consistent and were expressed as a score out of 21 and as a percentage (Table 5).

Discussion

The aim of the study was to evaluate changes in injury due to implementation of individual intervention programs that were designed using results of the injury audit and screening program. Results indicated a significant reduction of injuries between year 1 and years 2 and 3. A further reduction of injuries was noted between year 2 and year 3. As the intervention was based on performance enhancement using movement patterns and comprehensive injury audit data rather than injury sites, the conditioning programs took the form of “whole body” conditioning as it enables them to be better conditioned to withstand the rigors of modern day elite level ballet. However, a small increase in injury severity was noted over the study period. The literature suggests that a reason for an increase in severity can be due to an increased awareness of the period required to fully rehabilitate injuries to prevent recurrences.[30] Within this study the decrease in the recurrent injuries noted in both female and male dancers would support the notion that “extending” the rehabilitation period can help prevent recurrences.

Randomized control trials are recommended for intervention studies.[5] However; this can be impractical in high performance environments, as was the case in this instance. Van Mechelen’s injury prevention model[39] shows how, through repeated measures testing (using injury surveillance), the impact of interventions may be observed. The present decrease in injuries through the 3-year study period is in line with other published dance reports. [8,35] Those injury reductions have been linked to changes in the health care provision, namely by providing in-house health care[8, 35] and confirm calls for dance companies with an already established in-house medical team to explore further means to reduce injuries. Indeed, we examined the impact of individual conditioning programs designed using data from an injury audit and functional movement screening. The information from the injury audit provided the understanding of the injuries, while the FMS further contributed to the understanding of intrinsic risk. In other dance studies,[8,33,36] dance specific screening was used. This study chose a normal movement screening to establish the nature of movement outside of the skill and technique as a dancer to provide a more accurate indication of risk for when their skill or technique is diminished for any reason (for example by fatigue).

The intervention used in this study comprised of individual conditioning programs. The programs were designed using on information regarding intrinsic risk via the injury surveillance and FMS. The HIM was used to steer the construction of the conditioning programs. The HIM has at its foundation a basis in developing the correct neuromuscular firing patterns and motor control stability, key components of dance movement efficiency. These principals have shown good outcomes, where dance training consisting of components of balance, coordination, muscle flexibility and agility, saw an improvement in hip motion, joint mobility and sport related low back pain.[2] Research has also demonstrated the positive impact neuromuscular training has had on biomechanics, performance[27,28] and injury prevention.[23] Identifying areas of segmental deficit were also important as part of the program development. The benefit of isolated muscle training has been demonstrated in football.[3] Muscles groups like Gluteus Maximus and Piriformis have been advocated as playing a key role in improving force closure of the sacroiliac joint and subsequent improvement in stability.[34] With direct information regarding issues like lumbopelvic instability gained via the screening, these would be included within the segmental deficit training component of the intervention program. The use of functional integration in the final stage of each program was to challenge the neuromuscular firing patterns and segmental muscles groups in functional challenges to enhance their outcomes.

The intervention was designed to improve intrinsic factors such as muscular balance, stability and strength. The screening helped identify that the remarkable range of motion (noted with the “active straight leg raise” and “shoulder mobility”) can be at the cost of stability within key areas (a “give” or loss of control noted at the hips during “deep squat”, “hurdle step” and “in-line lunge” or winging of the scapula during “4-point kneeling”). Mechanism of injury (for example jumps/lifting partners) and injury history (for example injuries occurring at the end of rehearsals) recorded in the injury audit also suggested that strength and endurance would be beneficial areas to include in the conditioning programs.

It was felt that improvements to intrinsic risk factors may improve overuse injuries with the definition of an overuse injury being associated with a process of micro-trauma due to overloading.[12] Greater differences were noted in the reduction of overuse injuries compared with traumatic injuries This supports the use of intrinsically focused intervention programmes for dance, particularly as the presence of higher occurrences of overuse injuries has been reported. [1,8,3,29]

Limitations

A perceived limitation of this study was the failure to employ a randomized control trial for the implementation of the intervention program. Due to the multifactorial nature of injury it was decided to employ individual intervention programs that cannot be tested using a randomized control trial. This study elected to employ van Mechelen’s model of repeated measures to establish the foundation for the efficacy of the interventions employed. Further to this the validity and repeatability of the screening program had not been established within dance (although evidence exists in other sporting environments). However, the lead researcher with extensive experience in screening undertook all the screening for the study period to address inter-tester reliability. Further study into the reliability as well as predictive nature of the screening in dance would enhance our understanding. Finally, although the implementation of the HIM reflects a sound clinical reasoning process, the use of a previously untested model for the design of the intervention programs is a further challenge to the repeatability of this study. It is recognized that variations in workload, repertoire and the use of different guest choreographers may influence injury patterns. To ensure that the year 1 data was represented the typical workload of the company, a retrospective analysis was employed for the three years prior to the study (and the three years of the study). The repertoire remained relatively consistent, as did the use of guest choreographers; it was, therefore, felt that these factors would prove less of an influence in this study.

Conclusion

By combining injury audit and screening data and using the Hybrid Intervention Model to construct conditioning programs a significant reduction in injuries was demonstrated. The positive impact on injury incidence through the use of in-house medical teams in dance companies has already been demonstrated. In organizations that already have in-house medical teams a further challenge exists in reducing injury incidence. The results support the value of using injury audit data alongside normal movement screening to assist in the development of intervention programs as part of an injury prevention program in elite ballet.

References

1. Allen N, Nevill AM, Brooks JHM, et al. Ballet injuries: injury incidence and severity over 1 year. *J Orthop Sports Phys Ther*.2012;42:781-790.
2. Alricsson M, Werner S. The effect of pre-season dance training on physical indices and back pain in elite cross-country skiers: a prospective controlled intervention study. *Br J Sports Med*. 2004; 38:148-153.
3. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand JMed Sci Sports*. 2003;13:244-250.
4. Bahr R, Holme I. Risk factors for sports injuries -- a methodological approach. *Br J Sports Med.* 2003; 37:384-392.
5. Bahr R, Krosshaug T. Understanding injury mechanisms: a key component of preventing injuries in sport. [Review]. *Br J Sports Med.* 2005; 39,324-329.
6. Beales D, O'Sullivan P, Briffa N. Motor control patterns during an active straight leg raise in chronic pelvic girdle pain subjects. *Spine*.2009a; 34: 861-870.
7. Beales D, O'Sullivan P, Briffa N. Motor control patterns during an active straight leg raise in pain-free subjects. *Spine*. 2009b;34: E1-E8
8. Bronner S, Ojofeitimi S, Rose D. Injuries in a modern dance company. Effect of comprehensive management on injury incidence and time loss. *Am J Sports Med.* 2003;31:365-373.
9. Cook E, Burton L, Hogenboom B. The use of fundamental movements as an assessment of function-Part 2. *N Am J Sports Phys Ther.* 2006a; 1:132-139.

10. Cook E, Burton L, Hogenboom B. The use of fundemental movements as an assessment of function- Part 1. *N Am J Sports Phys Ther*. 2006b;1: 62-72.
11. Emery C, Meeuwisse W. The effectiveness of a neuromuscular prevention strategy to reduce injuries in youth soccer: a cluster-randomized control trial. *Br J Sports Med. 2007;* 44; 555-562.
12. Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scand JMed Sci Sports.* 2006; 16: 83-92.
13. Fuller CW, Molloy MG, Bagate C, et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Clin J Sport Med.* 2007; 17: 177-181.
14. Fuller CW, Ojelade EO, Taylor A. Preparticipation medical evaluation in professional sport in the UK: theory or practice? *Br J Sports Med.* 2007; 41:890-896.
15. Gamboa J M, Roberts LA, Maring J, et al. Injury patterns in elite preprofessional ballet dancers and the utility of screening programs to Identify risk characteristics. *J Orthop Sports Phys Ther. 2008;* 38: 126-136.
16. Hamilton WG, Hamilton LH, Marshall P, et al. A profile of the musculoskeletal characteristics of elite professional ballet dancers. *Am J Sports Med.* 1992; 20: 267-273.
17. Hincapie CA, Morton EJ, Cassidy JD. Musculoskeletal injuries and pain in dancers: a systematic review. *Arch Phys Med Rehabil.* 2008; 89: 1819-1829
18. Kiesel KB, Plisky P, Voight M. Can serious injury in professional football be predicted by a preseason functional movement screen? *N Am J Sports Phys Ther.* 2007; 2: 147-158.

19. Koutedakis Y, Jamurtas AZ. The dancer as a performing athlete: physiological considerations. *Sports Med*. 2004, 34: 651-61.
20. Koutedakis Y, Sharp NCC, eds. *The Fit And Healthy Dancer*, Chichester, UK: Willey & Sons Ltd,1999.
21. Liederbach MB. Performance demands of ballet. *Kinesiology for Dance.* 1985; 8: 6-8.
22. Luke AC, Kinney SA, D'Hemecourt PA, et al. Determinants of injuries in young dancers. *Med Probl Perform Art.* 2002; 17: 105-112.
23. Mandelbaum B, Silvers H, Watanabe D, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes. *Am J Sports Med.* 2005; 33:1003-1010.
24. Meeuwisse W H. Assessing causation in sport injury: a multifactorial model. *Clin Sports Med.* 1994; 4:166-170.
25. Meeuwisse WH, Tyreman H, Hagel B, et. al. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. *Clin Sports Med.* 2007; 17:215-219.
26. Minick KI, Kiesel KB, Burton L, et al. Interrater reliability of the functional movement screen. *J Strength Cond Res.* 2010; 24: 479-486.

27. Myer G, Brent J, Ford K, et al. A pilot study to determine the effect of trunk and hip focussed neuromuscular training on hip and knee isokinetic strength. *Br J Sports Med*. 2008; 42:614-619.

28. Myer G, Ford K, Palumbo J, et al. Neuromuscular training improves performance and lower extremity biomechanics in female athletes. J *Strength Cond Res*. 2005;19:51-60.

29. Nilsson C, Leanderson J, Wykman A, et al. The injury panorama in a Swedish professional ballet company. *Knee Surg, Sorts Traumatol Arthrosc.* 2001; 9: 242-246.

30. Orchard J, Seward H. Injury Report 2008. 090602 *Australian Football League* 2009; pp:1-14.

31. Pluim BM, Fuller CW, Batt ME. et al. Consensus statement on epidemiological studies of medical conditions in tennis, April 2009. *Br J Sports Med.* 2009; 43:893-897.

32. Pool-Goudzwaard AL, Vleeming A, Stoeckart R, et al. Insufficient lumbopelvic stability: a clinical, anatomical and biomechanical approach to "a-specific" low back pain. *Man Ther*. 1998; 3(1): 12-20.

33. Schon LC, Biddinger KR, Greenwood P. Dance screen programs and development of dance clinics. *Clin Sports Med.* 1994; 13: 865-882.

34. Snijders C, Vleeming A, Stoeckart R. Transfer of lumbosacral load to the iliac bones and legs. Part 1: biomechanics of self-bracing of the sacroiliac joints and its significance for treatment and exercise. *Clinical Biomechanics*. 1993; 8:285-294.

35. Solomon R, Solomon J, Micheli J, et al. The cost of injuires in a professional ballet company: a five-year study. *Med Probl Perform Art.* 1999; 14: 164-169.

36. Southwick H, Cassella M. Boston Ballet student screening clinic: an aid to injury prevention. *Orthop Phys Ther Pract. 2002;* 14: 14-16.

37. Twitchett E, Angioi M, Koutedakis Y, et al. Video Analysis of Classical Ballet Performance. *J Dance Med Sci.* 2009; 13: 124-128.

38. van Dijk CN, Lim LS, Poortman A, et al. Degenerative joint disease in female ballet dancers. *Am J Sports Med.* 1995; 23:295-300.

39. Van Mechelen W, Hlobil H, Kemper HCG. (1992). Incidence, severity, aetiology and prevention of sports injuries : a review of concepts. *Sports Medicine.* 1992;14: 82-99.

Dear Dr Hughes

Thank you for your reply of 20th November 2012 and the opportunity to revise and resubmit our paper to be considered for publication in CJSM. We would also like to thank you and the reviewers for your very positive and constructive comments.

We have now addressed all of the points raised by them and relevant changes/modifications are all indicated in the text. We attach below a point-by-point reply to the reviewers’ comments with the action taken and changes to the text. I hope that we have been able to comply appropriately with the suggestions made.

Kind regards

Nick Allen
Corresponding Author

Editor in Chief Comments:

Please see the comments from both reviewers.

There are just a few issues to address, and then your article should be suitable for publication in CJSM.

Best Wishes,
Dr. Christopher Hughes

AU: Thank you again for this opportunity to revise this study to be considered for publication in CJSM.

Reviewer Comments:

Reviewer #1:

Much improved over first version - still needs tightening up. See scanned pages for suggestions.

AU: Thank you for your kind comments. We have completed all the suggestions made and hope it now reflects the standard required for CJSM

Still needs conversion to "Americanized" (e.g., stabilization not stabilisation). [EDITORIAL OFFICE NOTE: As the publisher is American, this will be attended to during the copyediting process.]

Au: A spell check has been performed using English (US). Hopefully this addresses any spelling changes.

I am not sure Figure 1 is really needed - but have no strong objection to inclusion.

AU: I have left it with the submission at this stage but would be happy to have it removed if this was deemed more appropriate.

On page 10, you may want to better describe the reformer - although we use it in our rehab area - Iam not sure that people who do not work with a lot of dancers know what one is.

AU: I have included the full name of the reformer to better direct readers (i.e. Pilates reformer) as well as included a very short description

Be consistent in capitalization of "year 1" throughout.

AU: These have now all been corrected.

Paragraph/sentence (lines 265-266) is currently floating in isolation - I would recommend attaching it to an appropriate paragraph.

AU: Thank you. This has been moved to end of the results section.

Move discussion on choreographers to limitations section.

AU: This has now been moved to the limitation section

See scanned pages for other grammatical and stylistic suggestions.

AU: Thank you again for your comments. From the scanned pages:
The results section of the abstract has be reordered
Introduction text has been deleted, corrected and punctuated as suggested.
Injury Surveillance text has been corrected as suggested.
Functional Movement Screen (FMS) text has been moved, deleted and corrected as suggested
Statistical analysis text has had spelling correction made.
Results text has had the spaces inserted, deletions and grammatical corrections have been made as suggested
Discussion text has been corrected as suggested

Reviewer #2:

AU: Thank for your time and comments- I hope the corrections meet with your satisfaction.

Line 281, "percentage of total injuries of recurrent injuries noted in both female and male dancers": This is unclear and confusing. Of total injuries of recurrent injuries. Please clean up.

AU: Thank you- I have simplified this. I hope that it reads better now.

Line 331, change "strength and strength endurance" to "MUSCLE STRENGTH AND ENDURANCE." Strength and endurance are different measures, and I do not think you meant to say "strength endurance."

AU: the second strength has now been deleted.

Conclusion: You should have YOUR conclusion listed first, as in the conclusion of the study. This is in your last two lines. The first few lines refer to prior findings and studies. Your conclusion should state something declarative and clear like "We found that this happened when you do this or that." As it reads right now, it seems like your conclusion is that "The positive impact on injury incidence through the use of in-house medical teams in dance companies has already been demonstrated." That does not read like a real conclusion.

AU: This has now been rewritten stating our conclusion first.

Overall, the revisions were a nice improvement, and the study reads easier.

AU: thank you for your comments